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Verification Technologies for the International Nuclear Nonproliferation Regime

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Safeguards Science & Technology Group (NEN-1)

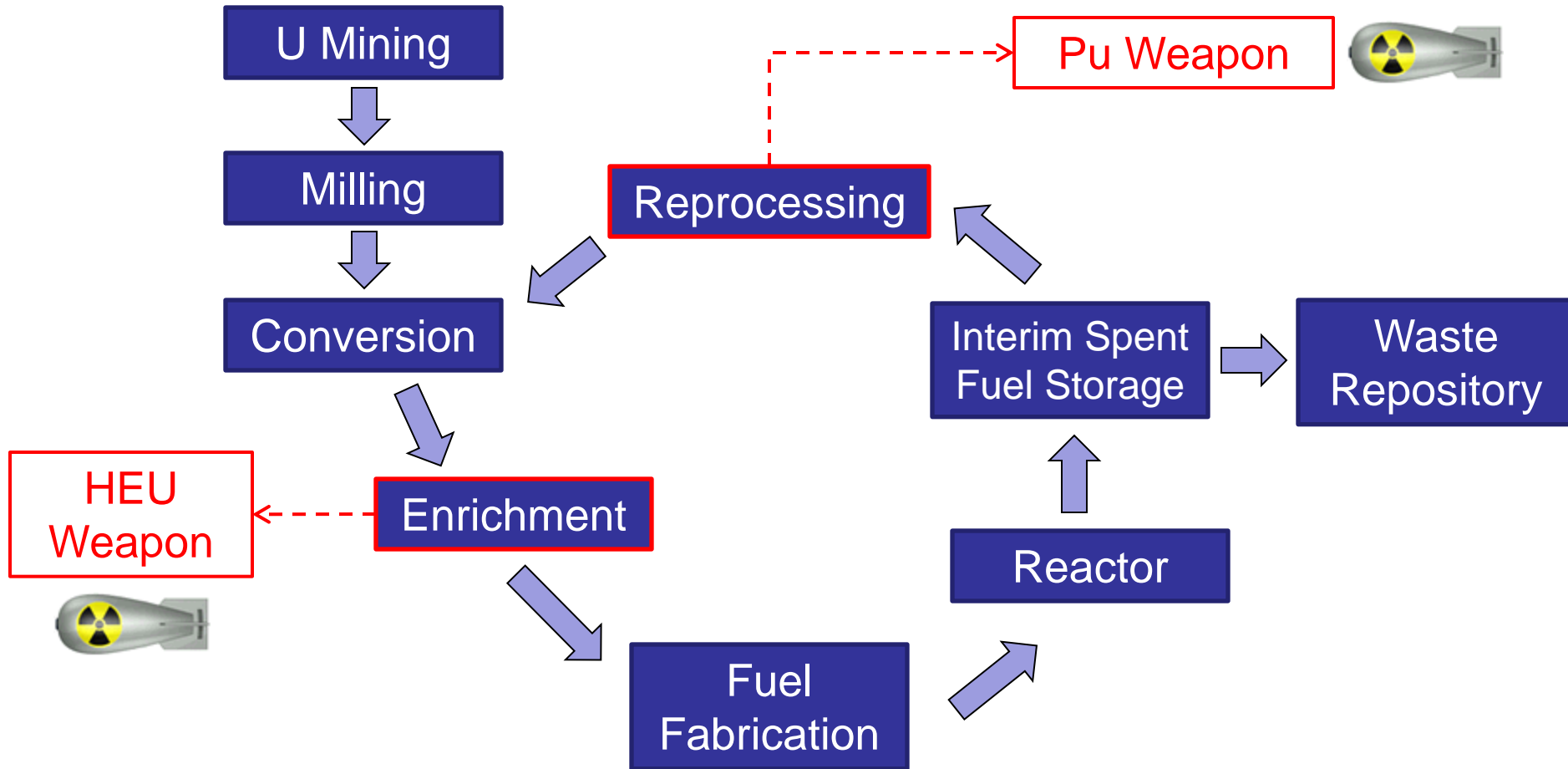
Science of Signatures Advanced Scholars Program

April 10, 2013

The Big Picture

- Global energy demands will continue to grow
 - Population growth + increasing standards of living (esp. in Asia)
 - Currently, about 2 billion people have no access to electricity
- Nuclear energy produces about 13% of the world's electricity with almost no greenhouse gas emissions
- Energy density is one of its key features
 - A single uranium fuel pellet contains as much energy as 480 m³ of natural gas, 807 kg of coal, or 149 gallons of oil
- But, nuclear technology has two faces
 - Extraordinary power to both create and destroy

The Nuclear Fuel Cycle



The Nuclear Nonproliferation Treaty (NPT)

- 1957: International Atomic Energy Agency (IAEA) established
 - Independent, inter-governmental organization based in Vienna
 - Maintains a unique relationship with the UN Security Council
 - Reports annually to the UN General Assembly regarding compliance by States with their safeguards obligations
- 1970: Entry into force of the NPT
 - Simultaneously attempts to prevent the spread of nuclear weapons technology and spread peaceful nuclear energy technology
 - Divides the world into nuclear weapons states and non-nuclear weapons states
- *Quid pro quo* of the NPT



Traditional Safeguards

- The purpose of safeguards
 - A system of accounting and verification designed to provide credible assurance that there has been no diversion of declared nuclear material and that there are no undeclared nuclear materials or activities
 - Safeguards are the cornerstone of the nuclear nonproliferation regime
- Implementation of safeguards requires the consent of the State
 - Comprehensive Safeguards Agreement (CSA)
- The first 20 years of safeguards focused on the correctness of a State's declaration
 - Detection of diversion of nuclear material from declared facilities
- Traditional safeguards include 3 key elements
 - Facility design information
 - Nuclear material accountancy
 - Containment and surveillance

Strengthened Safeguards

- In the 1990s, there was a perfect storm of activity that helped shape and win support for strengthened safeguards
 - Iraq, South Africa, North Korea – undeclared activities
 - The importance of verifying both the correctness and completeness of a State's declaration was recognized
- Measures under existing legal authorities
 - Environmental sampling
 - Greater use of unattended and remote monitoring instrumentation
 - Analysis of all info about a State – incl. open source and third party info
- Additional Protocol (AP)
 - Complementary access inspections
 - Expanded declarations to include more of the fuel cycle, all buildings on nuclear sites, fuel cycle R&D, exports of sensitive nuclear-related equipment, and the State's nuclear plans

IAEA Inspection Activities

- Verification of facility design information
- Auditing the accounting and operating records
- Updating the nuclear material book inventory
- Removing, inspecting, and replacing seals
- Collecting and reviewing surveillance tapes (film, video, digital images, unattended monitoring data)
- Independent measurements of nuclear materials (nondestructive assay) and sample collection for chemical analysis (destructive assay)
- Verifying operation and calibration of instruments
- Other activities as provided for in the safeguards agreement
- For AP States: possible complementary access

State Evaluation Process

- Identification of inconsistencies or indicators of undeclared activities
- Identify and prioritize follow-up actions
- Draw safeguards conclusions
- Analysis and integration of information from:

State Declarations

Facility design info
Operating records
Inventory reports
Voluntary reporting
AP declarations

Verification Activities

Inspection data
Environ. sampling
Material accountancy
Complementary access
Design info verification

Other Information

Third party info
Open source info
Satellite imagery
Geopolitical factors
Trade info
Scientific literature
News reports

Technology Development for Safeguards



Compliance
with safeguards
obligations



Technology
connects the two



Verification
of compliance

- Technology is the bridge that connects compliance and verification of safeguards obligations

LANL's Safeguards Science & Technology Group

- The best way to prevent nuclear materials from entering clandestine programs is to stop it at the nuclear facility
- Nuclear instruments for safeguards verification
 - Nuclear material accountancy – you have to know what you have to know if something is missing
 - Prototype and non-commercially available instruments
- We work in over 30 countries worldwide
 - Provides ground truth to a country's stated intentions and capabilities
- We have developed over 90% of the IAEA equipment approved for routine use
- We have trained every IAEA inspector since 1980

Examples



Uranium Cylinder Assay System (UCAS) for UF_6 cylinders



Passive Neutron Enrichment Meter (PNEM) for UF_6 cylinders



Plutonium Basket Counter (PBC) for Magnox spent fuel rods

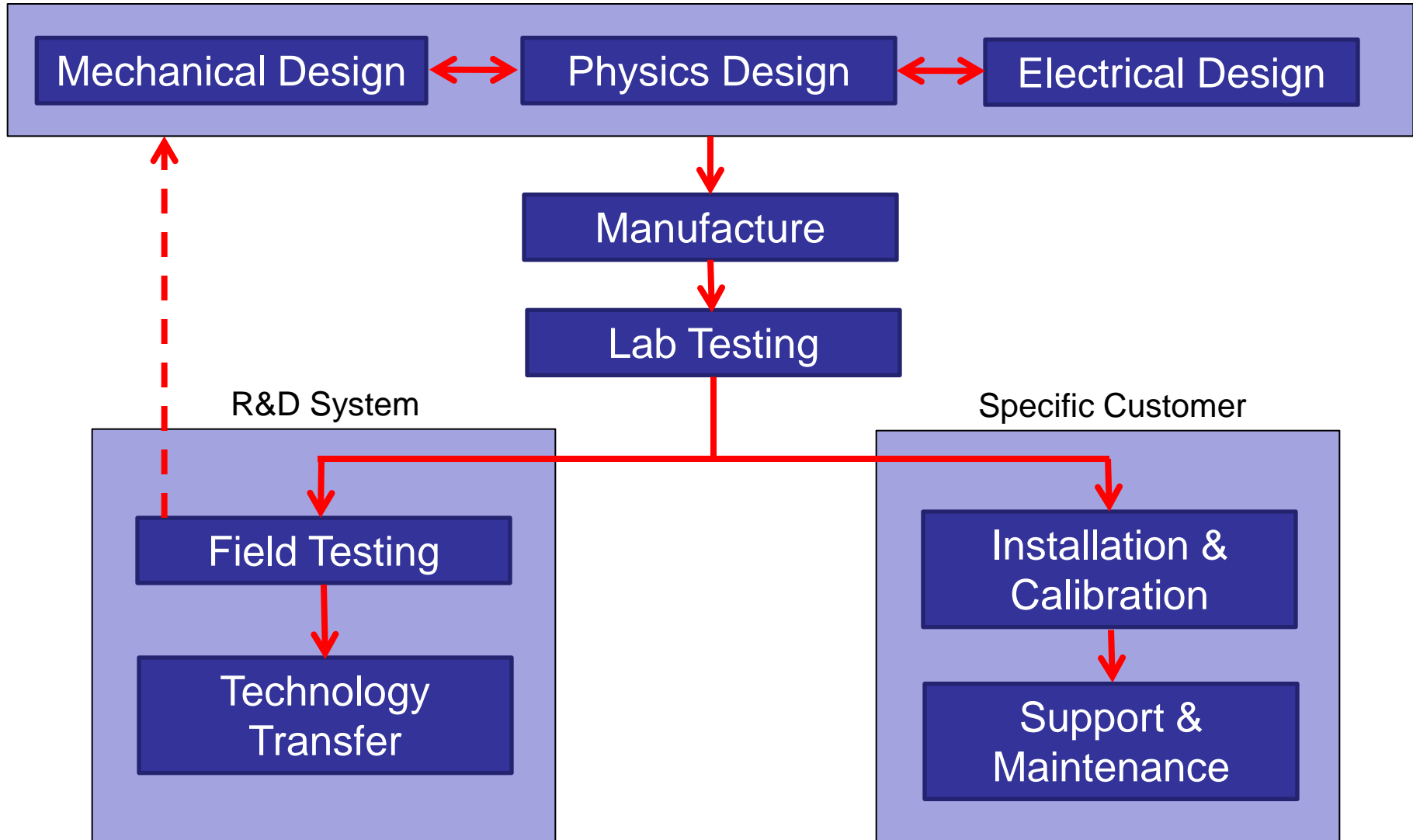


Improved Plutonium Canister Assay System 2 (IPCA2) for canisters of bulk MOX powder

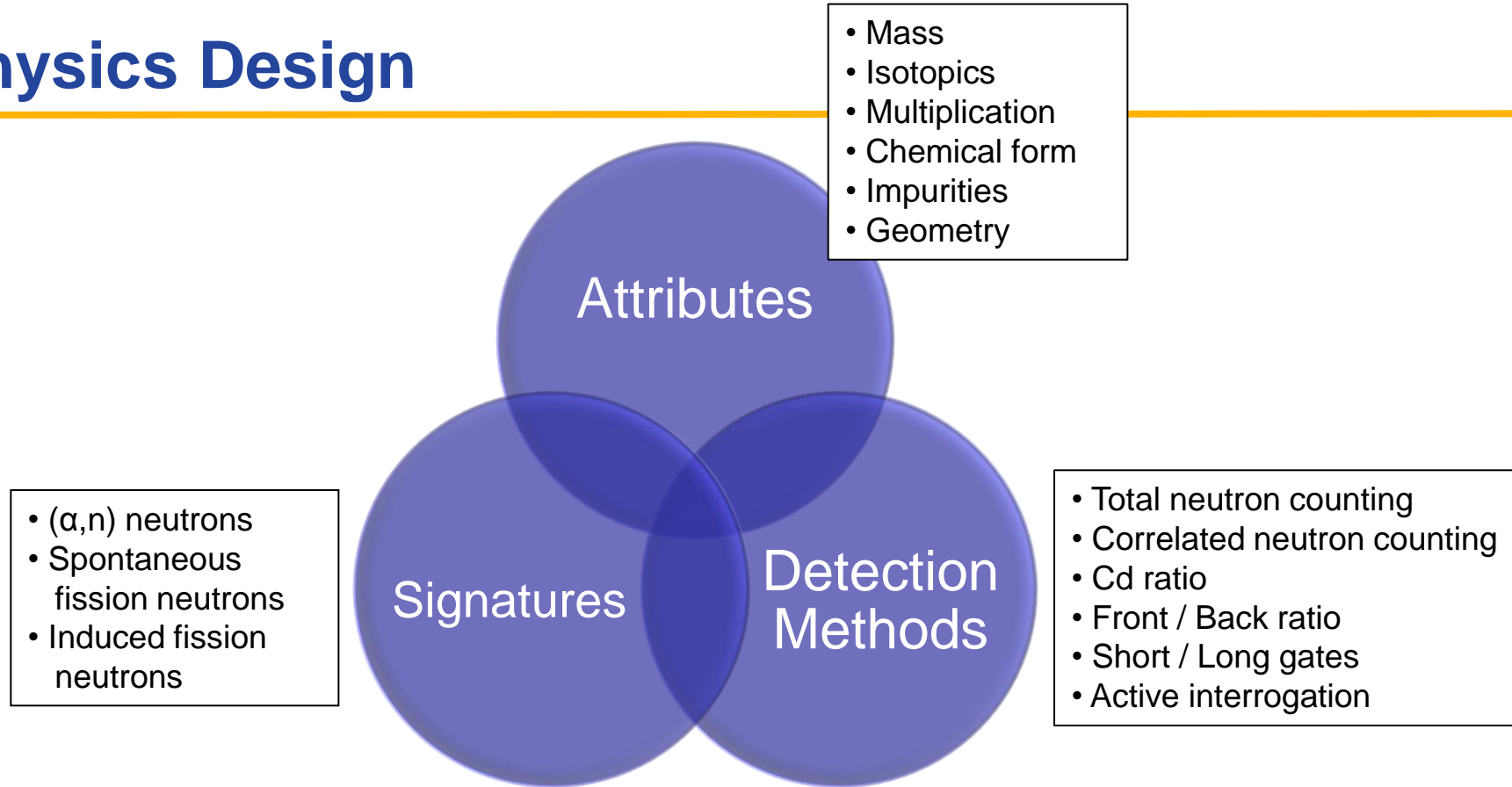
It Takes a Village... to Build a Detector

- Nuclear engineers
- Physicists
- Technicians
- Mechanical engineers
- Electrical engineers
- Project managers
- Software developers
- Facility operations
- Manufacturing
- Material suppliers
- Source custodians
- Radiation protection
- Administrative support
- Contractors

Detector Development Process



Physics Design



- Modeling and simulation play a major role in the physics design
 - Performance calculations
 - Detector optimization
 - Sensitivity studies

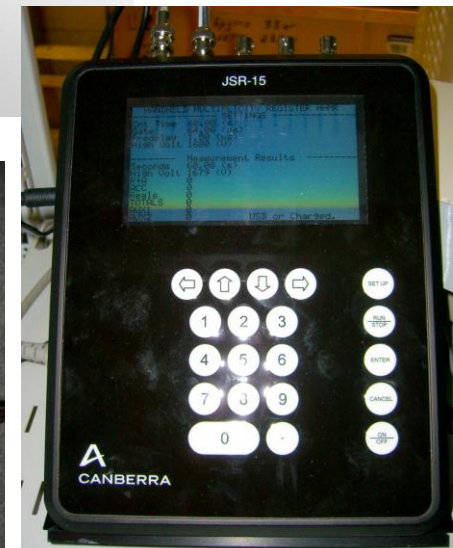
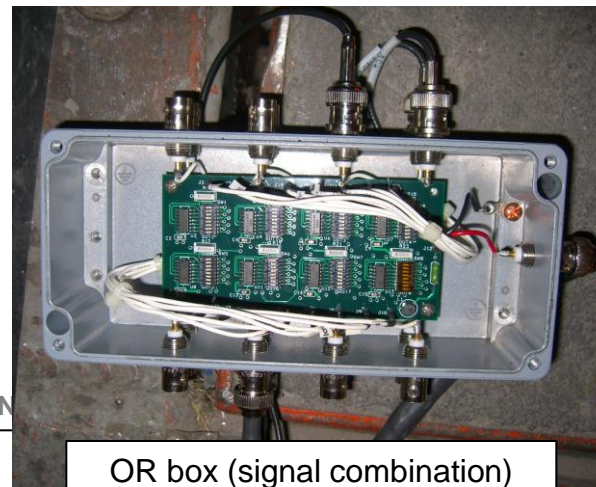
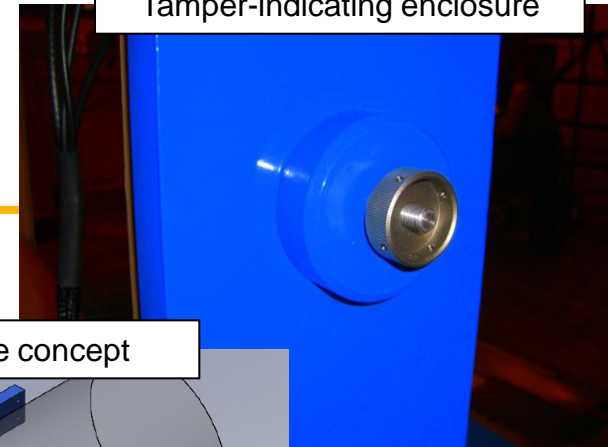
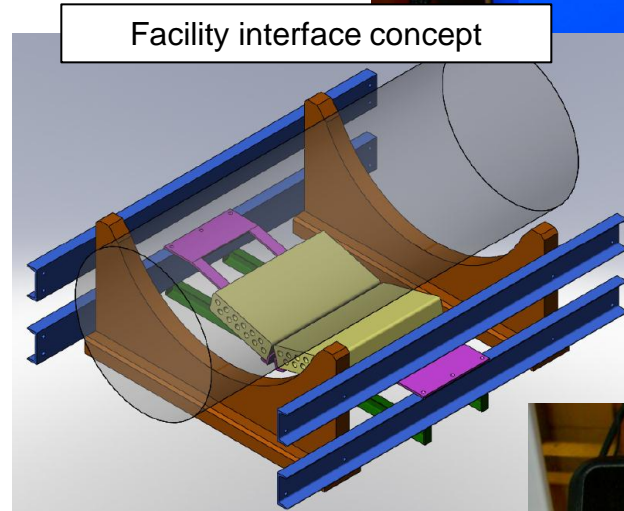
Mechanical & Electrical Design

- Mechanical considerations:

- Size and weight constraints
- Interface with the facility
- Manufacturability
- Seismic considerations
- Tamper-indicating devices

- Electrical considerations:

- Power requirements
- Preamplifier design
- Signal combination/splitting
- Cabling
- Data acquisition & software
- Environmental effects



Neutron data acquisition

Lab Testing

- Electronics
 - Gain matching preamps
 - Noise
 - Stability
- Detector characterization
 - Efficiency
 - Operating parameters
 - Model benchmarks
- Sensitivity to
 - Moisture
 - Temperature
 - RF background
 - Source positioning



IPCA2 cadmium tailoring & detector characterization



Mini-Epithermal Neutron Multiplicity Counter (Mini-ENMC) small UF_6 cylinder measurements



Advanced Experimental Fuel Counter (AEFC) underwater testing

Working in the Field



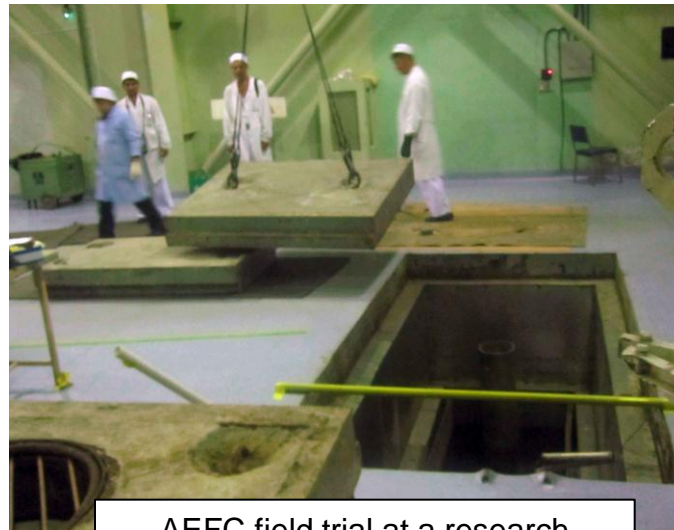
Nondestructive assay training course in Indonesia



Mobile Plutonium Facility (MPF)
exercise in the Nevada desert



PNEM field trial in a uranium
enrichment plant in Japan



AEFC field trial at a research
reactor in Uzbekistan



Core discharge monitor at a fast
breeder reactor in Japan

Safeguards: Past, Present, and Future

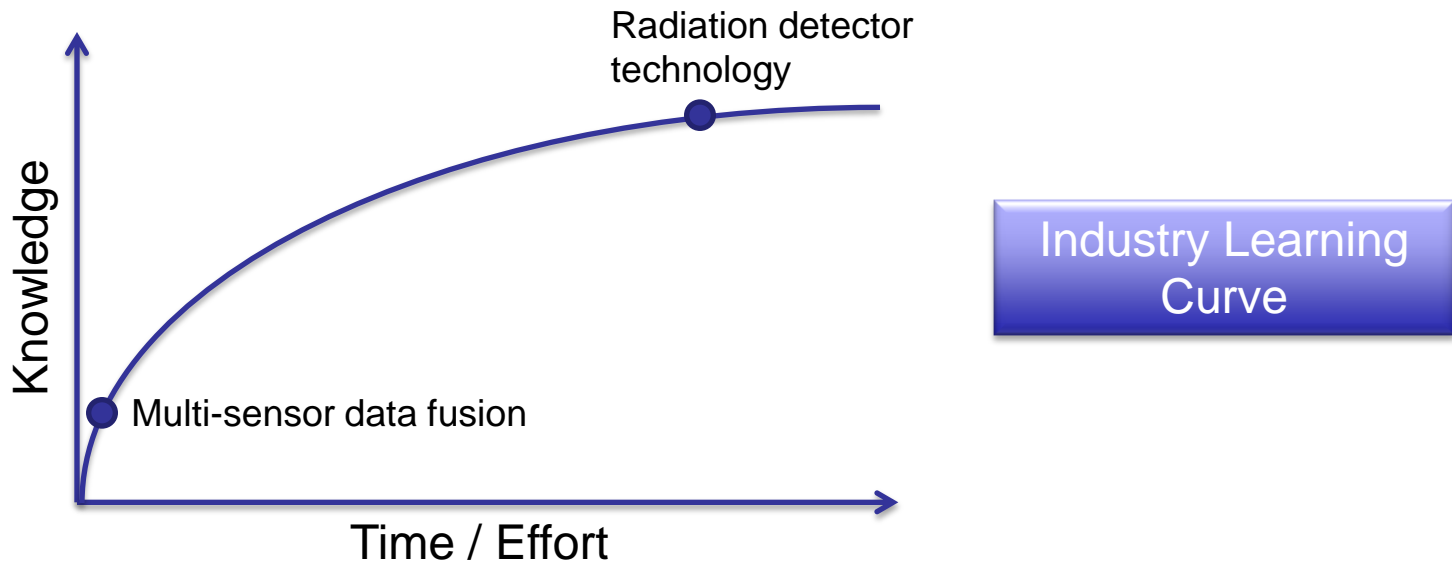
- Safeguards 1.0 (CSA)
 - Traditional safeguards
 - Focus on declared activities
 - Correctness of State's declaration
- Safeguards 2.0 (CSA + AP)
 - Strengthened safeguards
 - Declared and undeclared activities
 - Correctness and completeness of State's declaration
- Safeguards 3.0 ...
 - ???

Technical Safeguards Challenges

- Safeguarding uranium enrichment and reprocessing plants
- Reducing inspection man hours in facilities while maintaining confidence in safeguards conclusions
- Expanded use of unattended and remote monitoring
- Simplifying instruments and software for the average user
- New radiation detector materials and alternative sensor types
- Secure wireless and mobile devices
- Cloud computing infrastructure and high performance data environment at the IAEA
- Advanced data analytics

Multi-Sensor Data Fusion

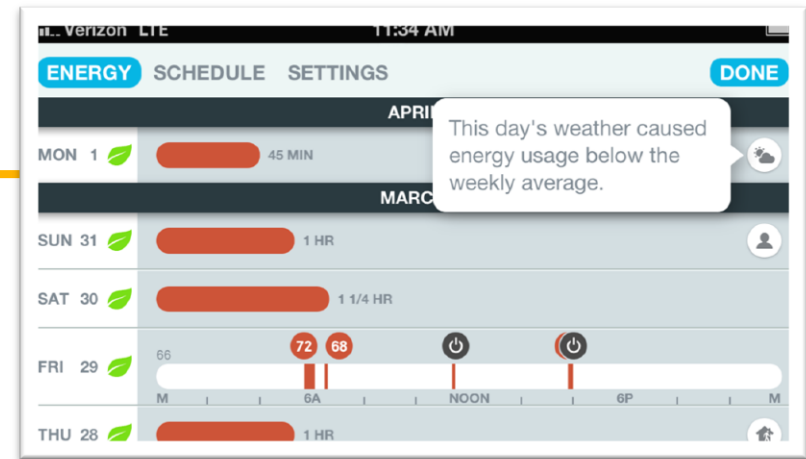
- Big growth potential in safeguards



- This is already a growing part of our everyday lives...
 - How can we better exploit it for safeguards applications in a way that is acceptable to both the IAEA and facility operators?

Nest Thermostat

- Motion sensor for Auto-Away feature
- Humidity sensor
- Temperature sensor
- Wi-Fi connection for weather info



Here's how you did:

This month you used 30 hours fewer than last month.

-30
hrs

January

121
hrs

February

91
hrs

Why did your energy use change?

We looked at a lot of reasons your energy use can change — from weather to Auto-Away — and these are the ones that made the biggest difference this month.

They add up to -31 hours of energy use. The difference of +1 hour was caused by other factors. [Learn more](#)



-20 hrs

Warmer weather helped you save.



-11 hrs

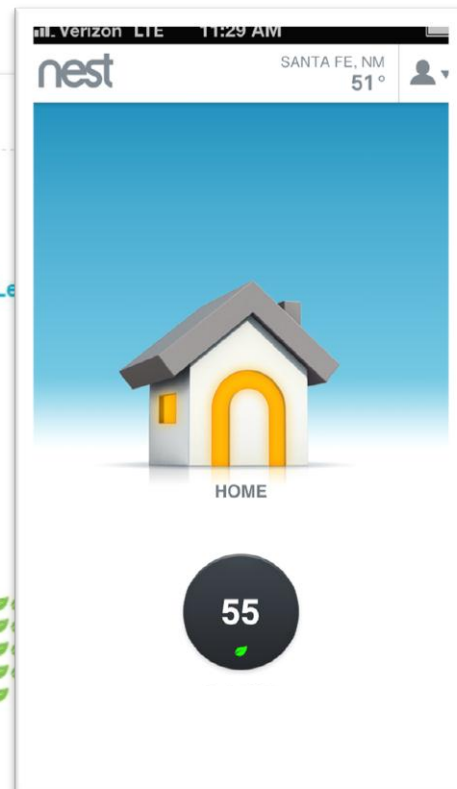
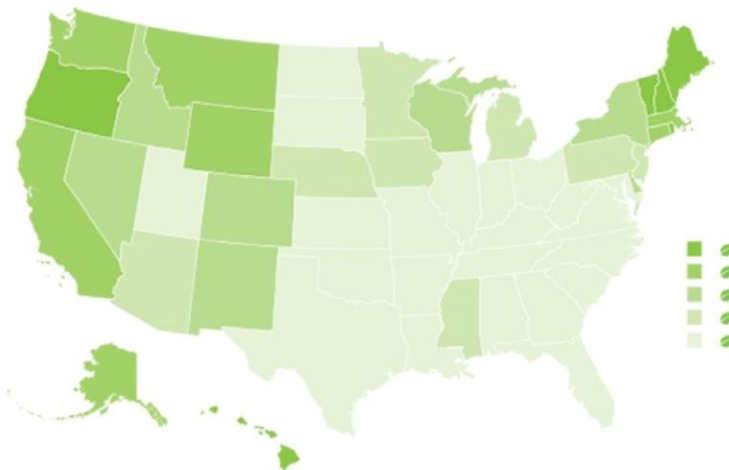
February had fewer days than January.

Interesting fact:

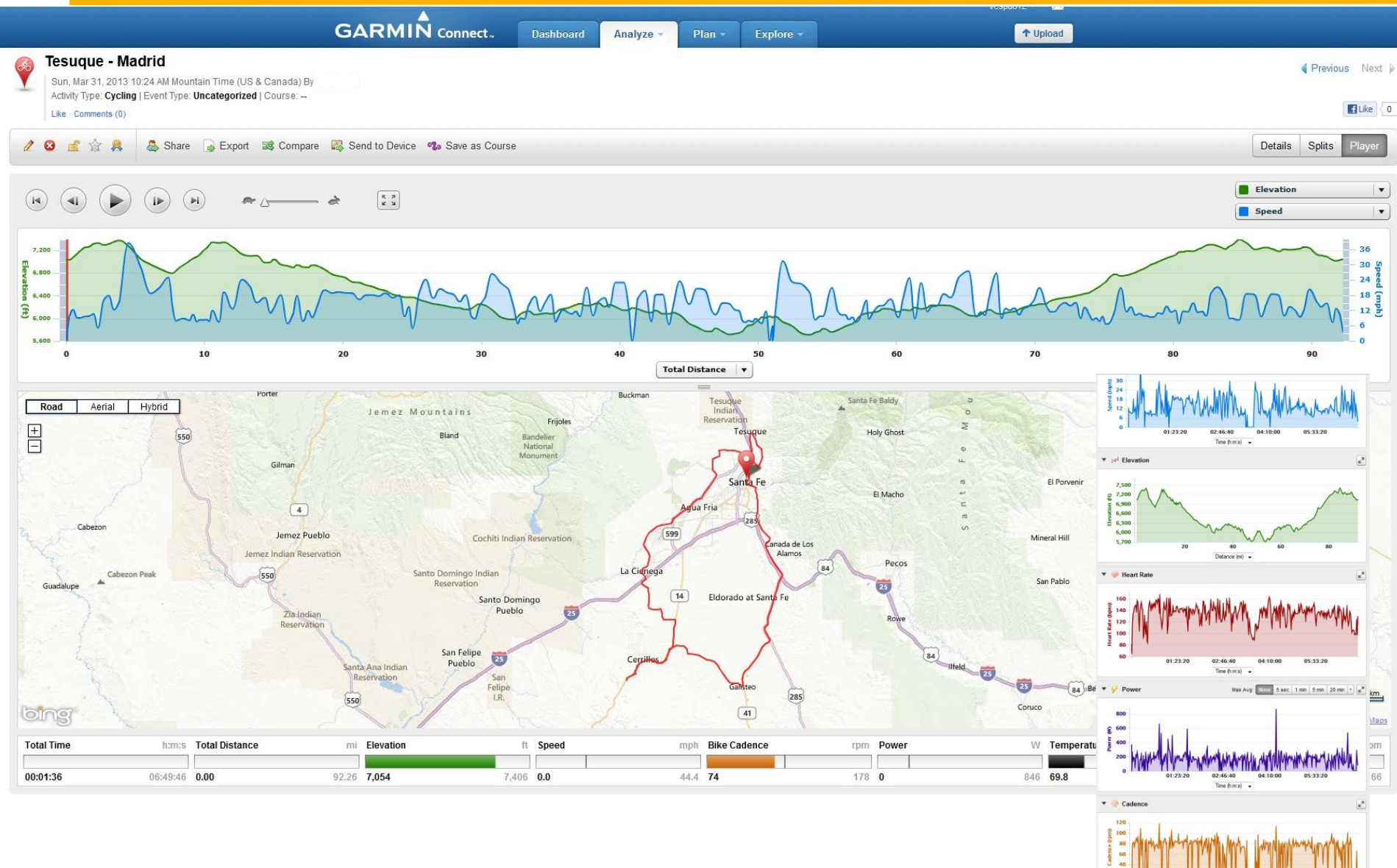
Since the beginning of 2013, you've earned more Leafs per month than:

- 25% of Nesters in your area
- 30% in New Mexico
- 35% of Nesters overall

How many Leafs you earn depends a lot on your climate and the weather. [Learn more](#)



Garmin Bike Computer + Speed & Cadence Sensor + Heart Rate Monitor



Conclusions

- Nuclear power is increasingly being seen as an important clean energy solution to meet global energy demands
 - The safeguards budget for the IAEA is expected to remain flat at a time when the number and complexity of fuel cycle facilities is expanding
- There is a clear need for novel and creative solutions that will allow the IAEA to deploy more efficient and effective safeguards
 - How can we do more with less?
 - The solutions will likely come from multi-disciplinary approaches that incorporate skills sets outside those used in traditional safeguards

Thank You

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